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General method of procedure in the working out of the Uncompahgre Valley Project, Colorado

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GENERAL METHOD OF PROCEDURE IN THE WORKING OUT OF THE UNCOMPAHGRE VALLEY PROJECT COLORADO

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On the 17th. of June 1902, Congress passed an act which may have appeared of little moment at that time, but which is now attracting the attention of the people of the United States. It is known on the Statute Books as the Reclamation Act and its purpose is to provide a Reclamation Fund, the said fund being usdd only to examine and construct Irrigation Works in certain Western States and Territories. This Act provides that the proceeds of the sale of public lands in thirteen States and three Territories, known as the Public Land States, less a deduction of five per centum for a school fund, should be expended under the direction of the Secretary of the Interior for the reclaiming of arid lands in those States and Territories. The reclaimed lands are to be subject to homestead land entry only and the settlers on them are to repay to the Government, in ten annual installments, their pro rata share of the cost of the irrigation works, thus making the Reclamation Fund apermanent one. The private lands included in Government Projects must be divided into units of 160 acres, of which the owner must sell all but one to bona fide settlers. This latter agreement must be complied with and secures to the Government the assurance that there will be no land speculation as none but seekers of a home would have any inducement to take the land.

Very few persons foresaw at the time the immense possibilities of the above Act. It has now assumed princely proportions. Already the Government has 35 Projects under actual construction, while it has approved several and is still yet examining into more. At the present time the Reclamation Service has under-

taken to provide water for an area of land larger than Great Britain. It has nearly completed the largest tunnel in the country(the subject of the present writing) and the two largest dams in the world while the West is simply dotted with miles upon miles of canal besides which the Erie is merely a name.

Naturally such a work is full of immense possibilities; it takes years to collect data sufficient enough to begin permanent construction. The irirgable area, the size of the canals and the structures all depend upon the volume of the water supply and this must be determined by experiments taken frequently over a long period of time.

The Reclamation Service pursues its work thoroughly, it leaves nothing to a haphazard guess because the responsibilities are so great and the dangers too imminent. Every stream is traced to its source, every irrigable acre and every possible reservoir site are mapped and located as thoroughly as modern engineering methods ban manage.

To further understand and appreciate the magnitude of such a work, we must go back a little and look over the geological, chemical, and other features of this western section of the United States. In the East irrigation is practically unknown. The low altitude of the land, the damp atmosphere, and the numerous rains and watercourses make it entirely unnecessary. Nature is the prime irrigator. But in the arid and the semi-arid West, with its deserts so numerous, it is an entirely different proposition. Here we have our streams, but with the high and the rugged country, and the low rainfall, most of the land is practically barren. The climate and the general healthfullness have attracted

many to the West and it only remained to provide a permanent means of support to make their stay a pleasant one. The results from the consequent study of the soil conditions were beyond the fondest dreams of the settler.. Numerous enterprises without Government sanction were commenced, some were successful and others were not; some failed because of the difficulty of the enterprise and otlers because of private corruption and graft which seemed to be so prevalent.

Probably the most notable work the Reclamation Service has considered since its organization is the reclaiming of the lands in the western part of the State of Colorado. Here we have a broad territory which holds forth the greatest promise of future ~~fertility~~, if only the magic influence of water could be provided. The Uncompahgre River from which the Uncompahgre Valley takes its name rises in the snowy summits of the picturesque San Juan Mountains. The river after descending into the valley, flows in a northwesterly direction until it finally ends its course, a hundred miles away, by uniting with the turbulent waters of the Gunnison. The river is not large and supplies only a limited portion of its basin. Its ouflow is small and may come at times when it will be of little use to the farmer, due to the fact that most of its waters is derived from snow and very little from rainfall. It is wholly inadequate to meet the demands made upon it, especially when it is considered that there are nearly 150,000 acres of irrigable land that can be farmed and will be as soon as a steady supply of water is obtained. A few miles away to the Norteast beyond the Vernal Mesa, the Gunnison River

has cut one of the deepest and grandest canyons in the country. For miles upon miles the river flows between rock walls that rise to a perpendicular height of from 2000 to 3,000 feet.

Here in the Gunnison River we have some of the clearest and purest water inthe State and it was not beyond the mind of man to see all this wisely spread over a valley that needed it so much. The idea was long conceived of diverting the flow from the Gunnison River as this was the only possible source of supply. Private enterprise interested itself in the work but the scope of the undertaking was beyond both private minds and purses. It then became a State proposition and the State of Colorado apprpp-riated $25,000.00 and built the State Tunnel for 1,000 feet and then finally allowed the matter to drop. This failure served to dampen the ardor of the gunnison Water supporters, and for years nothing more was done until the advent of a young and intrepid Government Engineer, Mr. A . L . Fellows, who soon saw the beauty of the enterprise and enlisted all his efforts in its successful accomplishment. He finally succeeded in attracting the attention of the United States Geological Survey and the preliminary steps were soon taken. General surveys were run and probable estimates of costs were made. The amount of land to be reclaimed was approximately determined to assure the Government that the undertaking was practicable and that it would not exceed in cost the value of the reclaimed lands. After having satisfied itself on this point, the Government marked the Project approved under the name of the Uncompahgre Valley Project, and the next step taken was to organize a Water User's Association.

The purpose of this association was to combine into a unit all the land holders in the valley who would eventually become users of the Gunnison Water. The Association through its stockholders then contracts to pay back to the Government the cost per acre of all the land irrigated under the Project. The payments are easy and are to be made in ten annual installments without interest, and the first payment is not to be made until after the first crop has been harvested.

The Engineering work then commenced and topographic parties were organized and put into the field to map the surrounding country. But before this could be done a triangulation system for the valley had to be established. These triangulation points were all selected with two objects in view; firstly to obtain good points with respect to being seen at great distances away; and secondly, to secure points that will make good triangles that is to have all the angles as nearly 60 degrees as possible, because it has been found from experience that by so doing ~~better and truer~~ more accurate results could be obtained. These points were then well set over the entire valley and all the angles were read and re-read and checked by different observers. The mean of all readings was taken and these angles were then assured to be the true angles and were used as such in computing their co-ordinates which was done in the Town Office.

The topographic parties were put into the field during the Spring and Summer of 1903. There were about eight of these parties in the field at ~~any~~ one time.

All topographic parties were organized as follows:-

1 Plane Table Man
1 Recorder
2 Rodmen

Each party had the use of one team and the men took care of their own horses. They obtained their meals whereever they would find it convenient.

The duties of the rodmen were to give sights on all the prominent features of the country, so that the topographer could map and sketch intelligently.

The topographer took sights on all these various positions of the rodmen by means of the alidade, and he called the rod-readings and the vertical angles off to his recorder who computed by means of the slide rule the distances away from the table and also the elevations of the several positions of the rodmen. These horizontal distances and elevations of the ground were then called back to the topographer and plotted directly in the field. Probably 20 to 40 shots would be given by both rodmen at any one excursion of the rodmen from the table depending of course upon the scope of the surrounding country, whether it was rough and rolling, or flat. The number of shots also depended upon the topographer and whether his accuracy of eye was well enough defined so as to enable him to do accurate sketching at a distance, merely by his own observation. The contour interval on these general maps of the valley was 10 feet and the scale of horizontal distance was 1" = 1,000'.. This contour interval varied in the topography taken contiguous to the Canyon, where 50' contours were used. These maps were then taken to the Town Office and inked in, care being taken to distinguish fence lines, roads

houses and other characteristics which would help an observer to locate himself more quickly.

Smaller maps of the Valley were then made from these larger maps of the Valley in order to get a more comprehensive glance of the country as a whole. These were then studied and detailed preliminary estimates were made.

The general outline of the work to be done in the valley could now be sketched out as a whole, and a general idea of what would have to be done to secure water to cover all of the irrigable land. Several questions then came up for discussion, the most important of whichwas to secure the most economical tunnel line. This problem was studied with great care and numerous engineers passed their opinions upon it. It may be noted here that in the Reclamation Service there is what is known as a Board of Consulting Engineers. Their duties are to travel from one Project to another, study all problems involved, give advice and remedy all radical errors. Consequently, if any error should creep in, one man it would be discovered by another. It may seem a useless expenditure to an outsider, but to one interested, it is the height of economy. It only tends to show the thoroughness of Government work and the best example as such was given in the recent earthquake in California. In San Francisco, the only buildings that really stood the shock well and escaped practically undamaged were Government Buildings. These Engineers then by constant and comparative study, finally agreed upon the Tunnel Portals, and these points were then plotted upon the general maps. The maps were then taken into the field

and the points were transferred as nearly as possible to the actual ground by means of chaining from known points. The bearing of the tunnel line was then read from the maps and a rough transit line was run over the Vernal Mesa through which it was proposed to bore the tunnel. This rough transit line checked as closely as could be expected, the flag set previously in the canyon and gave an excellent test on the thoroughness of the topographer's work. The main object was to determine the economic value of locating the Tunnel Portals, or, in other words, at what elevation should the water be turned into the valley to secure a sufficiency at the lowest possible expense. The rise in height of a few feet at the headgates in the river might serve to increase the cost by a more expensive construction at the Cedar Creek Portal. Then again by lowering the height at the headgates, it would serve to lengthen the tunnel in distance and would also cut out from possible irrigation many acres of good land. These points were finally determined, the location for the headgates was chosen, and also the point at which the Gunnison River was to be turned loose into the valley. Its elevation was about 6475 feet above the sea level.

These points were then located permanently, and a Gunnison Tunnel System of Triangulation was established and all the co-ordinates were computed with respect to their positions and the two end points of the tunnel tangent were tied to this system and tied repeatedly. It was then calculated that the tunnel tangent would be 30, 578 feet in length and would have a bearing of North 61 degrees 23 minutes 33 seconds East from the West or Valley Portal.

Ahubbed transit line was then run over the ground from one portal to the other and this line checked very closely, the line computed from the triangulation system.

The transit party consisted of:

Transitman
2 Flagmen
2 Chainmen

It was now decided to establish the tunnel line permanently, and concrete monuments for such a purpose were built. These monuments were sunk below the frost line and a brass scale was inserted in the top at right angles to the tunnel tangent. It was found that six monuments would be necessary on as many peaks, to secure a continuous and permanent line of sight over the hill. The alignment was tested repeatedly to prevent any possible error. In the daytime a transit was used and at dawn and sundown a Theodolite was used, at which time all possible tendency of error from heat waves would be eliminated. The tunnel tangent has also been checked and found to be accurate by means of slope board measurements.

Level circuits were then run from one portal to the other, and the double rodding system of levels was used.

The party consisted of:

Levelman and 2 Rodmen.

The levelman kept his own set of notes and each rodman also kept a set of notes on all Turning Points and Bench Marks. These bench marks were set with hubs or else were chiseled on rocks. On the second run of levels permanent Aluminum Bench Marks were set, and these were sunk in cement in solid rock ledges. It is a rather difficult run for the levelman being that it takes four and three quarter miles to ascend 2400 feet in vertical distance

from the West Portal side running to the Canyon, and it only takes one and one half miles to fall the same distance into the Canyon. Different routes were taken by the levelman in order to avoid as many errors as possible.

In the meantime numerous surveys were run to locate a tunnel road into the Canyon. The main object was to establish as low a grade as possible into the Canyon, because this road was to be used for hauling purposes. The road was finally completed and is 9 milesand 86/100 in length. It takes 6.4 miles to rise 2400 feet to the top of Vernal Mesa from the West or Cedar Creek Portal, and the same distance was dropped into the Canyon in a distance of 3.36 miles, which latter is approximately a 13% grade.

Having now finally determined the position of the Portals, the next step was to consider the elements of the tunnel design and this work was done during the Summer and Fall of 1904.

The sectional elements of the tunnel were computed from the usual formulae, Kutter's Formula being used to determine the coefficient and are as follows:

Carrying capacity of tunnel.....	1300 cu. ft. per sec
Wetted area.....	104.4 sq. ft.
Wetted perimeter.....	29.4 feet.
Hydraulic Radius.....	3.54
Slope.....	2.02 ft.per 1000
Coefficient of roughness.....	0.012
Maximum velocity.....	12.5 ft. sec

The tunnel is to be lined with concrete throughout and the completed section will be dimensioned as follows:

Bottom width	10 feet.
Width at spring of arch	11 feet
Depth of water	10' 4 1/2"

The size of the arch varies according to the class of material.

Having now finally determined all the sections and other points with respect to the tunnel, the next step was to prepare the plans for the bidders in order to let the contracts.

We will now close this preliminary work on the tunnel and take a glance at the other work on the project that has been going on in the meantime. A map study of the Valley was also made in this case to determine the route the water should take after passing through the tunnel.

It was originally proposed that the water should be carried from the tunnel by the South Canal for a distance of 12 1/2 miles until it reached the Uncompahgre River at an elevation of about 6200 feet above sea level. At this point headgates were to be built and one half the flow was to be diverted into the West Canal which would carry it a distance of 42 miles approximately. This canal would be constructed on the opposite side of the Valley from the South Canal.

The other half of the output of the South Canal would be diverted down the Uncompahgre River for a distance of 10 miles and would be finally turned into the East Canal about 1 mile south west of the Town of Montrose. The East Canal was to be about 25 miles long and would supply water to the central portion of the Valley. It was also proposed to divert a high line canal from the East Canal.

These first considerations have now been abandoned as the government has recently purchased the two largest and the most important canals inthe Valley; the Montrose and Delta Canal Located on the West side of the valley and the Loutsenhizer Canal located on the East side of the Valley. The West Canal will be built as originally projected, but its carrying capacity will be curtailed

to about 150 cubic feet per second as it serves but to irrigate a narrow strip of land lying between it and the Montrose and Delta Canal, which latter has a capacity of about 400 cubic feet per second.

The Loutsenhizer Canal, having at present a capacity of 125 cubic feet per second, will be enlarged and a supply of feed laterals will be built to keep it supplied to its full capacity and consequently the East Canal scheme has been abandoned entirely. In all probability the Government will purchase on e or two more canals and incorporate them into its system. The working principle is that it is cheaper and more satisfactory to build numerous laterals than to maintain headgates on the River and consequently most of the land to be irrigated will be covered by small laterals leading directly from the main canals.

The methods of running the preliminary and the final surveys of the centre lines of the proposed canals will be described for the South Canal only, as the same general methods were in force for both the other Canals.

In the first place, if the original triangulation system of the valley did not cover the points for the proposed line of Canal, a control triangulation system would be established and tied on to the main system.

Aparty of 7 men was then sent into the field in charge of a Transitman, who also acted as levelman. One day the men would run levels and the next few days or so the transit party would follow with the traverse line. The level party would be made up as follows:

Levelman
Rodman
Utilityman

The purpose of the party was to set grade stakes and temporary well flagged bench marks. A drop in elevation of about 2 feet per mile was allowed, and the preliminary levels were run with that in mind. Such a party could cover 7 miles or so per day.

The next day the transit party would take the field and would be organized as follows:-

Transitman
Head and Rear Chainmen
Head and Rear Flagmen
Utilityman

This traverse party would follow closely the levels run previously. The head flagman would endeavor to keep as closely as possible to grade and his sights would be given from 1000 to 3000 feet from the Transitman according to the roughness of the surrounding country. A stadia rod was used and after obtaining his line of sight, the transitman would direct his chainmen ahead for some distance and then they would direct themselves until they reached the forward point. No curves were run ~~in at all~~. All angle transit points were set with hubs and the stakes were driven on the line and numbered consecutively, and were 100 feet apart. The head chainman acted as stakemen and a supply of stakes was always kept near by the utilityman. When the transitman had finished directing his chainmen, he would turn his instrument on his rear flagman and after obtaining his line of sight, would direct his flagman to advance and give elevations on all the stakes previously set by the chainmen. The elevations were then read to

the nearest tenth of a foot, and were recorded by the transitman, who reduced his own notes. When the rear flagman had finally reached his chief, the transitman would advance to the next station and in the meantime the rear flagman would drive a small test hole either with a long chisel or with an augur. The purpose of this was to give a general idea of the composition of the ground and whether rock would be encountered very close to the surface or not. Such a party could accomplish from 3 to 5 miles per day; depending upon the range of country, and also upon the distance of the field work from the camp. Every 5 miles or so if possible, the traverse was tied on to the triangulation system in order to check the azimuth. The transitman also ran alternate lines whereever he had a reasonable doubt as to the best location and these alternate lines would be considered and estimates made when it came to making the final location. It was the duty of the camp draughtsman to make a copy of all the transit notes taken during the day, and on the following day he would recheck the level notes, and compute the latitudes and the departures of the traverse line and keep it up to date. From this data the plotting of the traverse line could be made on the sheets to be used later in taking detail topography. The scale used was 1" = 1000', and all the elevations of the respective stations were listed on the sheets so as to be a ready reference to the topographers. The topographic parties then took the field and were made up as follows:

Topographer
Handlevelman
Rodman

Five foot contours weretaken and scaled in by the topographer, and it was the duty of the handlevelman and rodman to find at what distance from the table each even 5 foot contour was located. This distance was chained as the rodman advanced and this he did in a line at right angles to the traverse line at the point over which the topographer was stationed. The topographer set his table over every 100 foot station and advanced consecutively along the line. The rod used by the rodman had its zero point at a distance 5 1/2 feet above the ground, which is the average height of a man's eye above the ground. The rod was graduated both ways from this point in feet and tenths of a foot. The handlevelman used a stick , with a notch in top end, in which the handlevel rested, and this notch was 5 1/2 feet above the ground. By means of such a rod the elevation of the ground could be read directly and no interpolations were necessary. The width of the topography taken would vary according to the country through which the line was located. If the ground was level and rolling, one or two five foot contours on either side of the line would carry us a distance away from the table 200 feet or so, and in rough country from 5 to 10 contours on either side of the line were taken and this was quite sufficient for the purpose of the work.

A party of this nature could cover on a average of from 1/2 to 3/4 miles per day, but of course this depends entirely upon the uniformity of the country and the speed of the topographer. When finished with his sheets, the topographer would turn them over to the draughtsman, and the finishing touches would be put on the sheets. All contour lines were inked in with

brick red ink, the traverse was put in green, all water courses and the like were put in blue, while the traverse line itself, fences, houses, and the like were inked in black. All the coordinate and section lines were shown as this served to give extreme detail to the sheets which would be of the greatest service to the future observer, especially in our next step which was to make what is called the Paper Location.

A general study of the country through which the canal is to pass is first made to determine the possible extent of all drainage areas, and in some cases it may be necessary to take the topography of these places. The purpose of this is to determine the size of the culverts that would have to be built to enable the flood water to pass under the canal safely, so that there may be no possible danger to the canal in the future from these floods. This data can be sometimes obtained from the farmers in the vicinity, but in cases has to be determined by actual observation.

Having this the next step is to determine the type section of canal to be used, that is whether earth or lined section, and also the distance each type section extends. In places where the canal passes through soft ground, we may have an earth section of large bottom width and side slopes of 2 to 1, and then again in firm ground we can have a much smaller bottom width. The type section for a canal depends upon the velocity assumed for the canal, the character and value of the land through which it passes, and the firmness of the soil. In places where we have heavy cuts, it is by far cheaper to line the canal with concrete, and increase the velocity as this reduces the excavation. On hillside work also it is better to have a lined canal as there is great danger of the canal slipping off if the channel were not lined.

In determining our elements our first step should be to determine the velocity we should have to be safe. If the ground is soft, we should use wet side slopes of a value of 2 to 1, and a dry side slope of a value of 1 to 1, but if our ground is firm a wet side slope of 1 to 1 could be used. The 1 to 1 and the 1/2 to 1 side slopes are used in all the lined sections, and almost any velocity is permissable in lined section. A 1/2 to 1 side slope is a slope whose horizontal distance is 1/2 the vertical distance.

The general system of construction in vogue is to use what is known as the cut and the fill method. That is to fix our grade at such a depth so as to use whatever ground is excavated to make banks on the lower side of the canal or on both sides if necessary. Having now determined the type sections and the distance each section will extend, we are ready to locate the line permanently in the field by using our topographic sheets as a ready reference. Our first step is to scale the Points of Instrument of the paper location from the topographic sheets. We have our preliminary line located inthe field and both the located and the preliminary lines on the sheets, and by scaling the distances of these points of instrument and running our located line from such data, both lines in the field will bear the same relation to each other as they do on the sheets. We chain the distances in the field generally from two stations on the preliminary line and set in a P.I. flag within two feet of the true distance and this is found to be accurate enough for our purpose.

The party is organized as follows:

Chief of Party
Transitman
Head and Rear Chainmen
Stake Artist

Head and Rear Flagmen
Levelman
Level Rodman
Two Laborers
Camp Cook
Camp Teamster

In the early morning the level party sets enough P.I. flags to last the transit party throughout the day. The method of procedure is as follows:

The transitman, chainmen, and stake artist are all together at one P.I. flag which has been hubbed and a tack set previously. The transitman, after sighting on the last P.I. flag where his rear flagman is giving him his line of sight by means of a steel range pole, turns his angle off to the next P.I. flag where the front flagman awaits his signals. The transitman turns off his angles to the nearest five minutes, as this saves interpolation in looking up values in the tables. The azimuth method was used in keeping the notes, and the zero point is at the South, and the azimuth progresses 360 degrees from South to West to North to East and back again to South. Having read his angle or the supplement of his angle, the transitman looks up the value corresponding to such angle in Searle's or Henoke's tables, and dividing this resulting value by four he obtains what is known as the tangent distance or the semi-tangent. (All curves were run in on a 25 foot chord basis and the tables in the handbooks are based on a 100 foot chord.) This distance is then chained in on the line from the P.I. over which the transitman is stationed to both tge other P.I's. and hubs are set and we have then located what are known as the points of Curve and Tangency. The transitman

then sets his instrument over his point of tangency and runs in the curve in 25 foot chords by means of the method of deflections. After chaining in the curve the chainmen proceed on the line towards the next P.I. flag. The head chainman sets a pony peg accurately on line every 100 feet and the stake artist who follows closely drives in a well marked stake corresponding to the station. After reaching the next P.I. the same method is employed. The speed of the transit party is variable, depending upon the number of curves and the length of each curve to be run in, but as a general rule from 8 to 10 curves can be run in during the day. The length of curve and the semi-tangent depends upon the exterior angle provided that the degree of curvature is constant. The greater the angle with a given degree of curvature, the greater will be the semi-tangent and also the length of the curve. The degree of curvature depends upon the character of the surrounding country, we may have as high a degree of curvature as 30 degrees but rarely does it exceed that value. A one degree curve is a curve whose arc subtends a chord of 25 feet with a one degree angle at the centre.

The transitman keeps his own notes and makes all computations; this can be done at odd intervals and time can thus be saved. The located line is tied on to the triangulation system whenever possible to check the azimuth. These checks cannot be made too often and very little time is lost thereby.

As was mentioned before, it is the duty of the levelman to set the P.I. flags for the transit party during the morning and to spend the remainder of the day in running his levels over the located line, reducing his notes as he advances. On regular stations, he reads to the nearest tenth of a foot, but on all

bench marks and turning points to the thousanth of a foot. It is his duty to note at what stations all gulches, streams, fences and the such occur. He also plots up his notes at night on the final profile which is carefully prepared. All possible data is put on the profile that may help to enlighten the engineer and the line is then divided into divisions.

The next step is to reference the located line especially if construction is to begin at once, and this and the Right of Way Survey can be accomplished at the same time and by the same party. The party generally consists of four men as follows:

Instrumentman
Assistant
2 Chainmen

The purpose of referencing is to tie in all Points of Curvature and Tangency to prominent land marks, such as mountain peaks, church spires, chimneys of houses, and to triangulation points whenever possible. The method is as follows:

The transitman sets his instrument over the point he wishes to reference and then searches the horizon for some permanent land mark which will make as nearly as possible a 60 degree angle from the located line. Having sighted and noted in his book the kind of object it is and made his diagram of the same, he then sets two or three hubs on each side of the line 200 feet or so away from the centre line and the distance to the point being referenced is paced. He then turns on some other land mark and sets two or three other hubs in the same manner as before, and at right angles to the first intersection line if possible. This constitutes referencing and if it should happen that at any

time the point on the located line should be lost or destroyed, he can produce both these lines to their intersection and obtain his point again. After construction also, by this method he relocates his line at the bottom of the excavated canal and rechecks his alignment throughout.

The Right of Way Survey consists in showing the relation between the located line and the section lines of the country. Before commencing the survey, the right of way man spends some little time in the General Land Office of the District, where he plots up the property owners through whose land the proposed canal passes. Having done this the men can then take the field. All sections corners are located and flags established at these corners so that one section corner may be easily seen and a line produced to the other. This line is then chained and the intersection of this line with the located canal line is hubbed and the station established and marked. The number of intersections found depends entirely upon the amount of land each property owner possesses, and also upon the manner in which this land is laid out and the general direction of the canal. This Right of Way Survey is necessary especially when the canal runs through private land for which the Government will have to reimburse the land holder. The right of way itself consists of a narrow strip of land from 50 to 150 feet on either side of the canal. This width depends upon the type section of the canal and also upon the value of the land through which the canal is going to pass.

This ends our preliminary survey operations, and if construction is not to begin immediately, nothing more in the line of surveying will be done, but if construction is to begin at once

the crosssection stakes must be set. This is done by the levelman. The type of section, grade of canal, and the bottom nad the top width of canal is known as is also the elevations of the surface stakes on the located line. These crosssections are set every 25 feet in rolling country but in fairly flat country every 50 feet will be sufficient.

The method used is as follows:

The levelman having set up and obtained the height of instrument, chains off at right angles from the located centre line and in both directions 1/2 the bottom and the top widths of the canal. At these points hubs are set and elevations are obtained and the stakes marked, so many feet cut or fill accordingly, and these stakes serve as guides to the contractor besides giving him his elevations. These cross sections were then plotted and computed by means of the planimeter and the entire excavation for the canal could then be determined.

CONSTRUCTION

At the present time on this project both the South Canal and the Gunnison Tunnel are under construction.

The entire West Canal has been located but only on the first half of the canal has the right of way survey been run and no referencing has been done at all. It is expected that construction operations will be commenced in the near future on this canal by means of the Co-operative System. That is the farmers and the homesteaders will be permitted to contract for small pieces of the work, and they will accept warrants as payment for the work done by them, and these warrants will be accepted at the completion of the project by the Government as partial payment

for the Gunnison Water.

The Concrete Headworks at River Portal have been completed and are ready for the installation of the gates and the hoists.

The design of the Wasteway and the Power Canal Outlet at the end of the Portal Cut have been completed and will be under construction during the coming summer.

The South Canal Outlet into the Uncompahgre River is also under construction and will be completed during the coming month.

CONSTRUCTION OPERATIONS

Bids were prepared for the first contract on the South Canal during the month of August 1905. The first contract consisted only of those parts of the canal as were of earthwork construction where no lining would be necessary. This portion of the canal was divided into 9 divisions and the bidders were required to bid on each division separately. The total contract involved the excavation of 700,000 cubic yards approximately in a distance of 4 1/3 miles. The divisions were not adjacent as their consecutive numbering might imply, but were spread over the entire length of the canal. The Government reserved the right to reject any and all bids at its discretion as was clearly stated in the contract.

The division of the material to be excavated was divided into four classes as follows:

Class 1 Material which could be plowed.
Class 2 " " " only be plowed after loosening with powder.
Class 3 Material in which rock masses occur not exceeding one cubic yard in volume.
Class 4 All rock masses exceeding one cubic yard in volume which require drilling and blasting.

The stating of so many yards of such a material in the contract was only an approximation and was used solely for obtaining comparative bids and to give a general idea of the magnitude of the work. The payment was made on the actual excavation at the bid price per yard as provided in the contract. The length of each division varied from 1400 to 3800 feet in length.

Bids were opened Sept. 15, 1904 and the contract was awarded to three bidders for the approximate sum of $85,000.00. One contractor received five divisions, another three, and still another one. The successful contractors then commenced work within thirty days as provided in the specifications, and the first nine divisions were completed satisfactorily on schedule time.

All of the earth excavated on the South Canal was of compact adobe, requiring from 4 to 6 horses on a plow and sometimes 3 men. Three different methods of excavation were used:

First- Excavation by means of Fresno Scrapers. 4 horses were required on each fresno, the capacity of each being about 1/2 cubic yard. This method of excavation is very efficient where the elevation is not toohigh and the haul does not exceed 200 feet.

When the range of haul to the waste dump lies between 200 and 500 feet it was found that the wheel scrapers would move the earth at less cost than the other two methods of earth excavation that will be considered. The organization in this case is controlled by the ability of the snap teams to do the loading.

The third and the last method used is the moving of earth by means of Fresno traps and wagons. This method is used entirely for long hauls. Platforms are built under which wagons can be driven.

An opening 24 inches square is provided for in the top of the platform in order to provide a means of discharging the earth directly into wagons. Three four horse teams can be used on each trap and these will load a wagon on each trip, consequently the number of wagons to be provided depends entirely upon the time it takes the fresnos to make the round trip.

The bids and specifications for the second contract on the South Canal were prepared during the summer of 1905. The contract involved the construction of the South Canal from Divisions 10 to 21 inclusive and included 7 masonry culverts, 16 pipe culverts, 3 tunnels ,and 5 drops. These divisions were not consecutive in stationing but were spread over the entire length of the canal. It was estimated that there would be 536,000 cubic yards excavation of earthwork, about 21,000 cubic yards of concrete and the laying of 2200 feet of pipe, besides other numerous and incidental diversions. The bridges over the canal three in number were of the Pratt Truss type and were built under a separate contract.

The bids were opened August 28, 1905, and the contract was signed Sept. 30, 1905. The entire contract was given to one bidder for the approximate sum of $515,000.00 The contractor began work the very next day.

In the construction of the South Canal numerous difficulties had to be overcome and this second contract consisted of these portions. This may be easily seen when it is considered that the canal fell 258.2 feet in a distance of nearly 12 miles. This fall in elevation is taken care of in a peculiar manner by

means of vertical and inclined drops and chutes.

The Gunnison water leaves the tunnel at an elevation of 6472.2 feet and for a distance of 1950 feet, it flows through what is known as the Portal Cut. This portion of the Canal is lined with 6" of concrete and has a bottom width of 10 feet add a depth of water of 9 feet. The construction is made through aheavy cut ranging from a depth of 50 feet at the mouth of the tunnel, until it finally dwindles to 10 feet at the end of the cut. The method of excavating this section is very interesting and can be spoken of more fully when considering the tunnel itself. At the end of the Portal Cut occurs Drop # 1 on the South Canal, and here we have a total fall of 57 feet in a horizontal distance of 1600 feet. The main drop is made up of five smaller drops ranging in fall from adistance of 10 to 12 feet vertically. These drops are built of concrete and have a bottom width of 42 feet and a length of 20 feet. The height from the bottom of the drop to the crest of the weir discharging into the drop is 15' 6" and the bottom elevation of the canal discharging from the drop is 5' above the bottom of the drop thus providing for a loss in elevation of 10 feet at each drop and also providing a discharge into a water cushion. About 348 cubic yards of concrete are required for each drop.

From this point the canal flows through earth section for a distance of 4000 feet until the next drop is reached. Drop # 2 is made up of two drops falling a total distance of 16.8 feet in a horizontal distance of 350 feet. One half mile farther on we reach an inclined drop that may be possibly called a chute. It consists of a total fall of 46.4 feet in a horizontal distance

of 350 feet.

From this point the water will flow through lined channel of 8' bottom width with 1 to 1 side slopes for a distance of 1600 feet or so until Tunnel # 1 is reached. This tunnel is to be 500 feet long and is to be lined throughout with concrete. The completed section will carry 1348 cubic feet of water per second with a velocity of 15 feet per second. It will be dimensioned as follows:

Bottom width	9'	6"
Width at spring of arch	10'	0"
Depth of water	8'	6"

There are three of these tunnels and the method used in describing one of them may be applied to all three. There are two classes of material used in respect to the construction of these tunnels:

Class 1 Material that will stand without being timbered.
Class 2 " " " not stand without being timbered.

And with respect to the concrete work, two classes are also used:
Class 1 Concrete less than 12" thick.
Class 2 " over 12" thick.

Class 1 concrete is used in Class 1 tunnel, and similarly with Class 2 concrete.

Tunnel # 1 is bored completely through and concreted. The material encountered was a hard blue shale, and no timbering had to be used. Hand drilling was used entirely in all these tunnels of the South Canal and the Jeffrey's Coal Drills were the ones selected . The length of the holes drilled varied from 6 to 8 feet in length and from 6 to 10 holes were drilled and blown during each shift. Only one shift of eight hours was worked per day and each shift averaged nearly eight feet in the heading. The tunnels were worked from both ends but it took much longer to

complete one portal than it did the other. The material was hauled from the tunnel to the dump by means of a car pulled by one horse and the length of the haul veried from two hundred to five hundred feet from the tunnel opening.

From Tunnel # 1 to Tunnel # 2 the water flows through lined channel a total distance of about 3000 feet. This tunnel is 400 feet long and is also completed. The material was the same blue shale as in the first tunnel but was a little softer and so had to be timbered throughout.

From Tunnel # 2 to Tunnel # 3 for a distance of 500 feet, the water flows through lined channel as before. Tunnel # 3 is 1000 feet long and is also completed. It was worked from one end only and the material excavated is the same blue Fort Benton shale as was encountered in the other tunnels. The shale was so hard that no timbering was required, except near both the portals where it had disintegrated.

Drop # 4, about 1000 feet from Tunnel #3, consisted of a series of seven vertical drops, each one falling a distance of from 10 to 12 feet and making a total fall in elevation of 78 feet. The total horizontal distance covered is 2500 feet and the drops are from 300 to 500 feet apart.

Drop # 5 near the end of the canal is an inclined drop, and consists of two inclines falling a total distance of 29 feet in a horizontal distance of 275 feet.

In putting in the lined channels on the canal especially in heavy cuts dry rubble masonry walls about one foot in thickness were first built and templets were then put in and the con-

crete laid in place. The contractors established a crushing plant in order to crush the rock used for the concrete. The plant was built near the Uncompahgre River, and the crushed rock was hauled to the various sections on the Canal where it was to be used. A good portion of the sand was also obtained from this plant. The rock was sized on screens. The crusher did not produce enough sand and so 1/2 the concrete charge was made up from river sand. Mixers were used and the proportions were as follows: 1 cubic foot of cement, 3 cubic feet of sand, and 6 cubic feet of rock, and this quantity made about 3/4 of a cubic yard of concrete. All the cement was furnished by the United States at the nearest Railroad Station but the contractor did all the hauling.

During the first winter it was found that some of the concrete lining that had been placed had cracked in several places due to the swelling ground and on the resumption of the canal concrete work the following Spring, it was decided to use rail reinforcement for the remainder of the lined portion of the canal. 3/8 inch round corrugated bars were used and were placed 24" centre to centre, both horizontally and vertically.

About 1500 linear feet of canal was not awarded under this second contract owing to the fact that an alternate line was under consideration and at the time of the completion of this contractthe matter had not been fully decided upon. This work embraced the excavation of about 1100 feet of lined section canal and 400 feet of tunnel. Bids were opened on this portion April 1, 1909. but as there was only one bidder and as that bid was considered too

high, it was rejected and this feature of the South Canal is now being constructed by force account under the direction of the United States Reclamation Service Engineers. It is expected that this work will be completed within three months.

The contractor on the South Canal kept a force account showinghis actual cost both in labor and material. By the terms of the contract, this force account was accessible to the Division Engineer of the Canal and a copy of the force account was sent in to the Montrose Office each month from which cost analyses were made showing the actual unit cost per item and especially as to whether the contractor was running on a profit or loss basis. Progress profiles were also prepared each month showing the actual yardage of excavation made during the month, and also the lineal footage of tunnel completed. These exhibits were made in addition to the regular monthly reports, and are filed in the Montrose Office for exhibition purposes.

THE GUNNISON TUNNEL

Bids were preparedfor the Gunnison Tunnel Contract and the contract was signed November 21, 1904. Work was begun January 1, 1905. It was proposed to bore the tunnel from both ends. At the River end no portal would be necessary owing to the steep mountain slopes, but on the Cedar Creek end opposite conditions prevailed. Here it was cheaper to excavate a cut ranging from 50 to 10 feet in depth than it would have been to drive a tunnel for that distance. The excavation of the Portal Cut and the Gunnison Tunnel were let in the same contract to one bidder. The excavation of this Portal Cut was begun January 1, 1905. It envolved the removal of about 130,000 cubic yards of

dirt and was to be lined throughout its entire length. The same method of keeping an estimate of the cost and paying for the excavation by classes was also used, as was the same general classification of material considered in the canal work.

The contractor began excavating directly over the mouth of the tunnel and by completing this portion first to tunnel grade, and then beginning the tunnel itself, swifter progress could be made. Excavation on the tunnel was begun February 28, 1905.

The tunneling at the River end was commenced January 1, 1905 and has been continuous since that time.

On May 27, 1905, the United States Engineers took over the direct charge of the construction due to the failure of the contractor, whose contract was then suspended, and since that time the work has been progressing under their direction by means of hired labor. Other bids were then prepared and were opened for consideration September 26, 1905, but the Government decided to reject all bids and to build the tunnel by Force Account under the direction of the Reclamation Service Engineers.

On May 11, 1905, a 5 foot by 10 foot single compartment shaft was commenced by the contractor, and was located at a point 4941 feet distant from the Cedar Creek Portal. The object of this shaft was to work towards both portals on reaching the tunnel grade. The tunnel grade was reached at adepth of 266.5 feet from the surface and the shaft was completed July 10, 1905. An average daily excavation of from 5 to 8 feet being made.

A new designation of tunnel headings was now put in force as follows:-

Heading # 1 - Tunnel running from River Portal.
" # 2 - " " " Shaft towards River Portal.

Heading # 3 - Tunnel running from Shaft towards Cedar Creek Portal.
" # 4 - " " " Cedar Creek Portal.

HEADING No. 1.

In this heading it was found necessary to build an inclined tramway running a horizontal distance of 200 feet with a rise in elevation of 22 feet. If the opening of this passageway were not placed at a height greater than any possible flood water could reach, it would not be possible to bore the tunnel at all. The inclined tramway is on a 25% grade and all the cars of muck are hauled out of the tunnel by means of a hoisting engine and dumped along the banks of the river by a stiff legged derrick.

For a distance of 6876 feet, Heading No. 1 was excavated to full section or to a section 12 feet by 12 feet. During August 1907, it was deemed advisable to reduce the section to 12 feet by 7 1/2 feet in order to secure greater speed and thus connect the headings in a shorter time, and since that date Undercut Heading only has been driven.

The best monthly progress accomplished in driving the full section in Heading No. 1 was made during May 1906, 383 feet being driven through a pink granite formation. The monthly progress in this heading has been variable, ranging from 121 feet to 383 feet, depending entirely upon the formation of the ground and the speed of the drill men. At times skilled labor was scarce and could not be had at any price. More or less water was also encountered inthis heading, the flow ranging from 20,000 to 300,000 gallons every 24 hours. Then again during the winter months the tunnel road would become impassable and the question of coal supply would become a serious one. All these causes

reduced the monthly progress in a marked degree.

The methods used in excavating this heading have been as follows: Up to October 1905, a drift was driven along the floor while later another gang would take down the roof of the tunnel. This method was early abandoned as it interffered with the ventilating and the tramming gangs in the tunnel, and consequently delayed progress in the heading. The heading and the bench method was then adopted and the bench was kept as close to the heading as possible, the bench being excavated by the down hole method of drilling. At the present time the full size of the Undercut Heading is being driven. As was stated before the excavation of the reduced section has been in progress since August 1907. In the Undercut Heading the progress has been variable depending upon the same conditions as described before for the full section excavation. The best progress was made during January 1908, when 449 feet was driven througha mica schist and a granitic gneiss formation. This is probably a world's record. During this month 3 shifts were used, consisting of 4 drillmen, 4 helpers, and 6 muckers on each shift.

Water has very seriously delayed the progress in the Undercut Heading. During July 1907, a flow of from 3 to 5 cubic feet of water per second was encountered but this delayed the heading crews only temporarily. During April 1908, another flow was encountered in the heading amounting to 600 gallons per minute. Of this amount 150 gallons per minute was discharged through the air line at the portal under its own pressure at a distance of 9000 feet from the face of the heading. Work was not again resumed in the heading until August 17, 1908, when the round that was drilled in April was shot.

On September 9, 1908, more water was encountered. The water came with such force that it took five hours to get the drill hole plugged. On September 14, 1908, another hole was drilled through a 3" pipe, this pipe being connected to the air line. The water seam was tapped and a flow of 250 gallons per minute resulted at the portal. An additional pump and generator were ordered and on December 27, 1908, work was again resumed in the heading and has been fairly continuous since that time with the exception of a few minor delays.

Electric motors are used to haul out the muck and a derrick to dump the cars, each car having a capacity of 1 1/2 cubic yards. Ventilation is secured by means of blowers and the men are now able to resume work in the heading within half an hour after shooting a round. All drilling is now being done by the 3" Sullivan Piston Drill. At the time the Government took over the work, the contractor was using a Water Leyner Piston Drill and the Reclamation Service continued the use of this drill until the organization could be perfected. It was then found that the Sullivan Drills are better adapted to hard ground and are not subject to excessive repair bills.

Throughout the tunnel the distinction of classes is as follows:

Class 1 - Hard rock which does not require arched lining.
Class 2 - Rock which does require arched lining.
Class 3 - Material that will stand with light timbering.
Class 4 - Tunnel thoroughly timbered throughout with 8" x 8" timbers.
Class 5 - Tunnel thoroughly timbered throughout with 12" x 12" timbers.

A first class power house has been established at the River Portal, equipped with all the latest machinery. The boarding house is run entirely by the Government as are all the bunk houses. For men and their families the Government puts up small cottages and charges anominal rent to pay eventually the original cost of erection.

HEADING No. 2.

The excavation in Heading No 2, was commenced as soon as the shaft had been sunk to the tunnel level and this was on the 12th. of July, 1905. This heading has progressed very rapidly and during June 1906, a progress of 624 lineal feet was made in this heading. The material encountered for the first mile was a blue shale. This is ideal to drive tunnel through, and it is claimed that the world's rate of tunnel progress has been broken in this heading for that class of material. The shale had to be lightly timbered as it disintegrated very rapidly. Drilling was done by means of The Jeffrey's Coal Augurs, and two rounds were drilled on each shift. In driving this heading , natural gas was struck about 400 feet from the shaft, and it came in such quantities that the men were obliged to use safety lamps for a time. However it has entirely disappeared by now.

All the muck excavated in Heading No. 2 up to the time headings Nos. 3 and 4 met was hoisted to the surface through the shaft. After the date of meeting all the muck was hauled through the tunnel to West Portal.

HEADING No. 3 .

Heading No. 3, working from the shaft to the West Portal end, was not commenced until January 16, 1906. Its progress was made through the same blue shale as described in the foregoing account of Heading No. 2. The shale became softer as the heading advanced and at the point of meeting of the headings the formation consisted of adobe and gravel. This heading is timbered throughout. The daily progress was variable and gradually decreased as the heading advanced. About 1305 feet from the shaft, a cave-in occurred which broke in the timbers but fortunately no one was injured. This portion of the tunnel has been thoroughly retimbered and all danger totally eliminated.

HEADING No. 4 .

Heading No. 4 was commenced February 28, 1905, and has been worked continuously since that time. The excavation was commenced in adobe soil and all the muck was hauled up an incline at the mouth of the tunnel until the Portal Cut was completely excavated. The material through which the heading has been driven has been adobe soil mixed somewaht with gravel, requiring heavy timbering throughout. The daily rate of progress was slow and varied from .6 to 8.5 feet per day. Three cave-ins have occurred in this heading since it was begun. The most serious occurred on May 30, 1905 and imprisoned all the men working in the heading for two days. Five of these were killed and the remainder were finally rescued by driving a shaft down from the surface.

Heading No. 4 was driven by using the Crown Bar System of Tunneling. 12" by 12" timber sets are placed 3 feet centre to centre and insome places it has been found necessary to reinforce

these with intermediate timbers. Heading Nos. 3 and 4 met on July 3, 1906, 1906 feet being driven in Heading No. 3, and 3036 feet in Heading No. 4 .

In all the headings three shifts are worked eight hours each, and the blasting is done at the end of each shift. The men lose very little time waiting for the smoke to clear off. Ventilation is supplied very quickly and effectively by blowers no diffieulty is experienced in that way at all.

Electric power is used in all the headings and all the Government houses are lighted by electricity, which is a great convenience. Drying rooms have been established and the men are compelled to take care of themselves. Government hospitals have been established at both the portals, as have been schools also, and the best of sanitary regulations have been put in force.

After the completion of the work in Headings Nos. 3 and 4, excavation in Heading No. 2 progressed as heretofore with the exception that all the muck was hauled through the tunnel instead of being hoisted through the shaft. During November 1906, a flow of water of 20,000 gallons per day was encountered but was passed after a few days delay, but On December 19, 1906, a flow of 10 cubic feet per second was encountered. This flow carried carbonic acid gas into the heading and stopped the work for the time being. Inorder to improve the ventilation in Heading No. 2 and to lower the temperature, it was considered advisable to drive an inclined ventilating shaft about 4,000 feet closer to the heading. This shaft was 4 feet by 7 feet inside the cribbing timbers, 679 feet long and the angle made with the horizontal was 51 degrees 8 minutes. This shaft was commenced on January 12,

12, 1907 and was completed March 17, 1907. Shaft was excavated by means of two drifts, one sinking from the surface and the other upraising from the tunnel, 251 feet being excavated in the sinking from the surface and 428 feet in the upraise from the tunnel.

After the completion of this shaft it was found that the temperatures in the heading had been reduced considerably and work was resumed in Heading No. 2 on March 25, 1907.

During August 1907, the Undercut Drift was commenced in Heading No. 2. The Undercut Drift is equivalent to 2/3 full section. The heading progress has been fairly continuous since the resumption of work, with the exception that practically the whole month of July 1908 was lost as far as progress in the heading was concerned.

It will be remembered that the tunnel at West Portal is located very close to the Cedar Creek Channel, and on June 30, 1908, a cloudburst came down Cedar Creek, flooded out the Power House, and tore out the dam across the Cedar Creek Channel at West Portal, thus allowing the water to flow into the old Cedar Creek Channel over the tunnel bore. The tunnel was broken into, timbers were washed out, and the tunnel itself was filled with gravel and silt for a distance of 100 feet. The Portal Cut was also filled with debris varying in depth from 14 feet at the mouth of the portal to 6" or 7" at the mouth of the portal floor in the cut.

On May 1, 1909, Heading No. 1 was excavated to Sta. 102+59 and Heading No. 2, was excavated to Sta. 115+03, thus leaving 1244 feet of Undercut Heading yet to be excavated.

GUNNISON TUNNEL HEADWORKS

In order to secure the best location for the headgates, it was found necessary to leave the tunnel on the straight line

tangent at Sta. 2+05, and to excavate on a curve what is known as the Approach to the Headgates, 204 feet in length. The excavation for the headgates proper was then commenced and envolved the removal of about 1716 cubic yards of loose rock and 4090 cubic yards of solid rock. The excavation and the concreting of the Headworks have been completed, 341 cubic yards of concrete being placed mixed in the proportion of 1 : 2 : 4

Two steel gates have been provided for both gates being about 7 feet wide by 12 feet high and operating under a maximum head of 25 feet. The gates are built up being made of I Beams and Channels and are operated in a 12" groove in the concrete Face rollers are provided to transmit the water pressure to the concrete face and each gate will weigh approximately 3000 lbs. One hoist is provided for each gate and aspecial interlocking device permits the gates to be dropped instantly. The headworks are completed with the exception of the installation of these gates.

Concreting Tunnel

Heading No. 1 - 863 linear feet of concrete floor and 359 linear feet of arch and sidewalls have been completed to date, a total of 930 cubic yards of concrete being placed in that distance mixed in the proportion of 1 : 2 : 4

Heading Nos. 2 - 3 - 4 - 12352 linear feet of concrete floor and 8318 feet of arch and sidewalls have been completed to date mixed in the proportion of 1 : 2 1/2 : 5, an average of 1.25 cubic yards of concrete being required for 1 linear foot of arch and sidewalls. At the West Portal the Gravel Pit is located

only a short distance from the shaft used originally to hoist the muck from Heading No. 2. Excavation at the pit is made into side dump cars of 35 foot capacity; these cars are run on an average distance of 75 feet to a hopper at the top of the chutes, which separates the material on grizzly screens and discharges into storage bins at the bottom of the chutes. The gravel and the sand is then hauled half a mile to the main chutes located in the shaft which discharges directly into the mixer in the tunnel at the bottom of the shaft. Two men are employed at the mixer, one to apportion the sand, gravel, and cement, and the other to keep the cars in place for filling with concrete. Another man is employed at the top of the shaft to tend to the storage bins and chutes and to run the hoist cage in the shaft.

The following is the method used in placing concrete in Heading Nos. 3 and 1 by means of the "Jumbo Traveller".

The jumbo frame is a large frame, in the form of the letter "H", which rolls on wheels over a temporary track outside of the main track of the tunnel. This frame is of the proper width to just clear the concrete lining forms and to leave sufficient space in the lower open section below the platform to allow loaded muck cars from the heading to pass through. In the centre of the forward end of the frame is a motor and hoist by which the cars of concrete are hoisted to the platform above. This platform is level and is approximately 6 feet above the track below. Along the centre of this platform is a track so that the cars of concrete can be run off of the hoist cage and on to the platform from which they are dumped directly into boxes along each side of the track between the track and the forms. From these boxes the concrete is shovelled directly into the arch or walls with a lift of only

four or five feet.

The organization of the gang working was as follows:

1 Foreman
1 Motorman
1 Brakeman
3 Men mixing
2 men placing forms
2 Men tearing down forms
5 to 6 Men placing concrete

The above organization was not strictly adhered to in all cases. The hoist was usually run by the brakeman. While the cars were being hoisted, the the men that were placing forms, or the two men that were tearing down forms, depending upon the amount of work each gang had to do, uncoupled the cars and ran them on to the hoist cage.

In placing the concrete, the arch and the walls were carried along at the same time, the walls being as a rule from 10 to 12 feet ahead of the arch. The walls could not possibly get more than from 15 to 20 feet ahead of the arch, and this only after moving the jumbo frame. The main advantage of this method is in the use of power to hoist the concrete; the main disadvantage being that the concreting of the arch can be carried on from only one point. It takes about one hour each day to move the Jumbo.

Method of placing concrete in Heading No. 2

The Jumbo Traveller cannot be used in this heading on account of the ventilation pipe, consequently two general methods have been in use, one in which the arch and the sidewalls would progress simultaneously, and the other in which the walls were put in first and the arch afterwards.

In the first method four men were used in placing the arch and two men in placing the sidewalls. The men placing the con-

cretain the sidewalls would shovel the concrete directly from the cars into the walls, while in placing the arch the concrete was handled twice, two men would shovel the concrete from the cars into boxes placed on a temporary platform and the two remaining men would then shovel into the arch.

The second method was practically the same as used in the first case just described, with the exception that the arch was shoveled into placeworking from both walls towards the centre. The unit cost for labor in concreting Heading No. 2 was practically 33 1/3 % higher than the Jumbo method used in Headings No, 3 and 4 due to the necessity of handling the material twice in the placing of the concrete arch.

In Heading No. 1, no general method has benn pursued, the concrete is placed in the various weak sections in the tunnel and consequently the cost is greater and no comparison can be made betweenthe East and the West Portals. The rock and the sand used for concreting in this heading have to be crushed and screened which makes the unit cost very expensive.

The geology of the country has been very accurately determined. The Vernal Mesa was tested and found to be a sandstone on the surface with a granitic rock as a core. The valley itself was carefully examined and determined to belong to the Fort Benton Shales, with the natural adobe on the surface, and here and there we find numerous outcrops of sandstone. Numerous occurrences of land going to seep have occurred, but this has happened through too much water.

The lateral system for the valley has been studied and a general scheme will soon be put in force. The Farm Unit Values under the Project have also been determined, the general idea being to allow a 40 acre farm unit in cases of rich sandy loam suitable for a fruit farm, and to allow 80 acres for a farm unit in cases of adobe soil. This Farm Unit Report classifies every acre of land in the valley and states whether it is irrigable or nonirrigable, and fromthis report the basis of what each farmer or property owner will have to pay will be made as soon as the project is completely finished.

It is expected that the headings will meet during the coming month of June and that all the distributing canals will be completed within a few years.

Steps are now being taken to have the opening celebration during August of the coming summer and it will be a grand notable day for Colorado. The country is rich in everything and it is not a question of what can be raised but what will be raised. The largest orchard in the State is within a mile of the Town of Montrose. Travel the country over, one finds apples of all kinds, peaches pears and cherries. Here we have our luscious strawberries, and our numerous aviaries. The cattle of the vicinity carry off the blue ribbon at all the fairs, and for the sportsman bear and deer can be found within fifty miles, while the desciples of Enoch Arden have the grandest trout fishing grounds in the country within twenty five miles of Montrose.

The Uncompagre Valley Project is probably the only one of the Government Projects that possesses such beauty of scenery within such a short distance. Here in one day we may ride from Montrose into a Canyon that sets a man's mind a trembling, with all its mighty peaks and its natural grandeur. Thenagain we can take a walk to the suburbs beyond the houses and the trees, and a beautiful vista of mountains is opened before us with all their lofty peaks that even now are white with snow.

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